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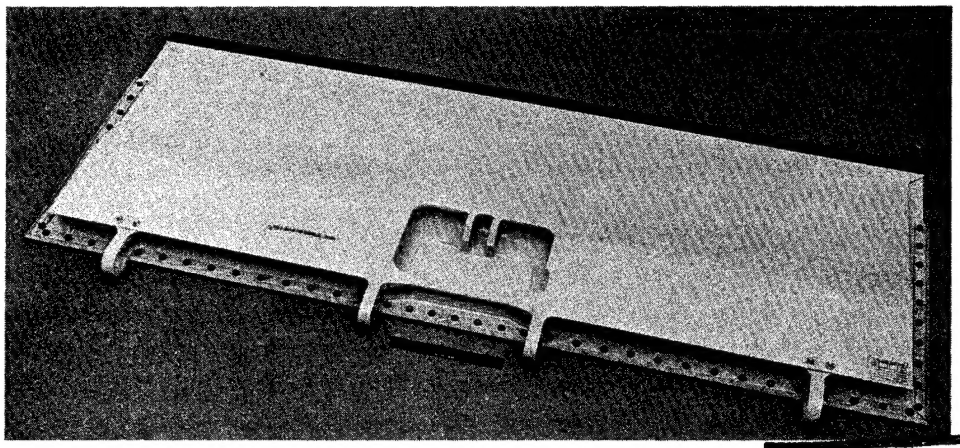
737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

By Robert L. Stoecklin



THIRD ANNUAL REPORT
APRIL 1976 THROUGH APRIL 1977

Prepared under contract NAS1-11668 by
BOEING COMMERCIAL AIRPLANE COMPANY
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for
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16. Abstract

The third annual flight service report was prepared in compliance with the requirements of contract NAS1-11668 and covers the flight service experience of 110 graphite-epoxy spoilers on 737 transport aircraft and related ground-based environmental exposure of graphite-epoxy material specimens for the period from April 1976 through April 1977. Four spoilers have been installed on each of 27 aircraft representing seven major airlines operating throughout the world. A flight service evaluation program of at least 5 years is under way. As of April 30, 1977, a total of 766 938 spoiler flight-hours and 1 168 090 spoiler landings had been accumulated by this fleet. Based on visual, ultrasonic, and destructive testing, there has been no evidence of moisture migration into the honeycomb core and no core corrosion. Tests of removed spoilers and of ground-based exposure specimens after the third year of service continue to indicate modest changes in composite strength properties.

Ten advanced-design, all-composite spoilers were introduced into the program beginning December 18, 1975. All ten were withdrawn from service in August 1976 following an adverse experience in which polysulfone skin panels reacted to Skydrol hydraulic fluid. Redesign of the all-composite spoilers is planned.

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FOREWORD

This is the third progress report on the service evaluation of graphite-epoxy flight spoilers for 737 aircraft. This effort has been conducted as a portion of NASA Contract NAS1-11668, "A Study of the Effects of Long-Term ground and Flight Environment Exposure on the Behavior of Graphite-Epoxy Spoilers." The program is structured to gather and evaluate actual commercial service experience on a large number of graphite-epoxy specimens in a wide range of operating environments. Additional annual reports will be prepared and submitted for the duration of the flight service period, which is intended to provide at least 5 years of flight service.

The program is administered by the Langley Research Center of the National Aeronautics and Space Administration. Mr. Richard Pride of the Materials Division is the technical monitor.

The program is being conducted at the Boeing Commercial Airplane Company by Robert L. Stoecklin, technical leader, under the direction of J. E. McCarty, program manager.

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737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

Robert L. Stoecklin
Boeing Commercial Airplane Company

PROGRAM SUMMARY AND STATUS

This third annual flight service report is submitted in accordance with the requirements of contract NAS1-11668 and covers the service evaluation portion of this NASA contract for the period of April 1, 1976 through April 30, 1977. Segments of the data contained herein have appeared in previous documentation (refs. 1 and 2).

A primary objective of this program is to produce 114 graphite-epoxy 737 flight spoilers for laboratory testing and service evaluation deployment. One spoiler of each of the three different graphite-epoxy material systems used has been laboratory tested for stiffness and strength in partial fulfillment of FAA certification requirements. Four spoilers were initially installed on each of 27 aircraft representing six major airlines operating in different environmental circumstances. These units will be monitored under actual load and environmental conditions for a period of at least 5 years. Selected units are removed periodically to evaluate any material degradation as a function of time. Six environmental exposure racks have been fabricated and positioned at major airport terminals of the participating airlines in various parts of the world to gather ground-based environmental data to support the flight data gathered from the spoilers.

An additional objective of this program is the fabrication, certification, and deployment of 12 advanced-design, all-composite spoilers which are physically interchangeable with, and can be substituted for, the graphite-epoxy spoiler units deployed in the primary portion of this program. These 12 units are intended to participate in the flight service program to the maximum extent possible and no removals are scheduled.

All information regarding the fabrication, processing, and developmental testing of the all-composite spoilers leading to FAA certification has been documented in the manufacturing and test report prepared for this program (ref. 3). All information relative to the flight service program involvement will be documented within this reporting system.

Significant events that have occurred during this period include:

- Completion of the third annual inspection of the spoilers in service
- Continuation of the spoiler repair program
- Continuation of the NDI sampling program and static-testing of spoilers from the flight service program

- Expansion of the flight service program at Frontier Airlines to a second aircraft
- Withdrawal of the all-composite spoilers from the flight service program
- Extension of laminate moisture absorption study

As of April 30, 1977, a total of 766 938 spoiler flight-hours and 1 168 090 spoiler landings had been accumulated by the fleet. The high-time spoiler has accumulated 9 219 flight-hours on Frontier Airlines 737 N7386F. Thirty spoilers have accumulated in excess of 8 000 flight-hours since the beginning of the flight service program.

Based on postservice inspections, there is still no evidence of moisture migration into the honeycomb core and no evidence of core corrosion itself. A third example of exfoliation corrosion of aluminum edge members has been discovered. Investigation of this problem points to accidental breaching of the corrosion-inhibiting system prior to final bonding in fabrication.

Laboratory testing of spoilers returned from 3 years of flight service testing shows varying deterioration rates for the three material systems. Additional testing of spoilers fabricated with T300/5209 skins and zero flight service yields a scatter bond for the strength data. Tests of additional ground-based exposure specimens following 3 years of exposure are included.

Maintenance damage and related repair activities have been conducted at a modest level in the past year. Four spoiler panels sustained ground-handling damage which was repaired by Boeing and the panels returned to service. Only one additional actuator-interference problem has been identified.

Deployment of the task II all-composite spoilers progressed through installation of five shipsets (two panels per aircraft) with five participating airlines by August 1976. In early August, one operator reported a lower surface delamination during a routine inspection. Following examination of the delaminated panel, all 10 task II spoilers were removed as a precautionary measure and returned to Boeing. Further use and deployment of these spoilers is under study.

Airline participation interest in the program continues at an enthusiastic level. One operator has volunteered the following comments:

> *In my opinion, if these spoilers had been provided as original equipment on our 737's, we could have reduced our maintenance expenditures considerably. In addition, if similar design had been incorporated on the airlerons, elevators, rudders, tabs, and other secondary components, significant maintenance savings could have been realized.*
>
> *I would like to encourage you to incorporate the advances demonstrated by your program in as many components as possible or practical. I recognize that we are far from your largest buyer of aircraft, but we believe our operation subjects the B-737 to one of the most punishing environments in the world. . . . .*

FLIGHT SERVICE EXPERIENCE

SCOPE OF PROGRAM

The service evaluation program was established to place the 737 graphite-epoxy flight spoilers into a commercial service environment containing as many climatic variables as possible. The six active participating airlines previously identified (ref. 2) continue to operate the 27 aircraft originally committed to the program. Frontier Airlines has committed one additional aircraft, giving a new total of 28. The current participating airlines are:

- New Zealand National Airways–four shipsets (16 spoilers)
- Aloha Airlines–four shipsets (16 spoilers)
- Deutsche Lufthansa Airlines–six shipsets (24 spoilers)
- Piedmont Airlines–eight shipsets (32 spoilers)
- VASP Airlines (Brazil)–four shipsets (16 spoilers)
- Frontier Airlines–two aircraft (6 spoilers)

The geographic scope of the service-evaluation program continues as shown in figure 1.

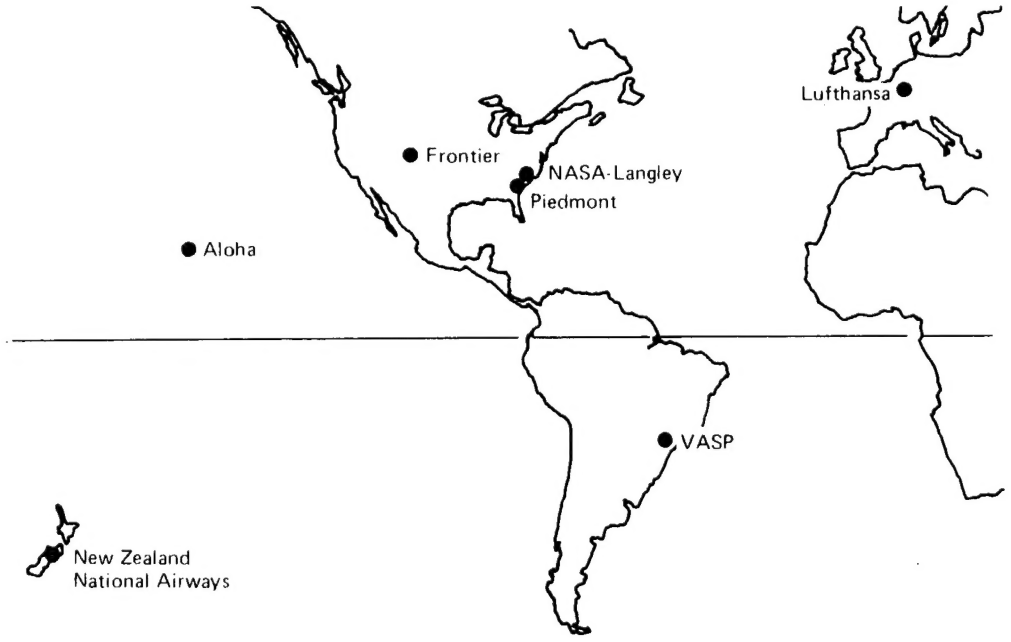

Figure 1.–Geographic Deployment of Current Participating Airlines

FLIGHT EXPERIENCE

The flight service evaluation program, in operation since July 18, 1973, has achieved an exceptional level of commercial service exposure of graphite-epoxy structural aircraft components, in the form of the 737 flight spoiler. The program has generated over three-quarters of a million flight hours of service in its 3.8 years of operation and is adding flight experience at the rate of nearly 20 000 hours per month.

The total flight experience to April 30, 1977 is detailed in table 1, with the breakdown by the spoiler serial number. Reinstallations are treated as a separate line item in this summary. Note that each of the graphite-epoxy material systems is designated by a separate block of serial numbers:

- Union Carbide T300/2544: 0001 to 0038
- Narmco T300/5209: 0041 to 0078
- Hercules AS/3501: 0081 to 0118

Table 2 summarizes the same data by airline. VASP and Frontier data include only flight experience since acquisition of their respective aircraft from PSA.

The flight experience of series 0300 all-composite spoilers has been compiled in table 3. No series 0300 spoilers are currently in service.

SPOILER REMOVALS

The spoiler removals discussed in the first and second annual reports (refs. 1 and 2) have declined significantly in this reporting period. There has been only one additional rod-end blister problem reported. Four additional spoiler panels have been returned for maintenance-related damage and one unit was returned for exfoliation corrosion. The spoiler returned as surplus (ref. 2) has been returned to flight service status. A breakdown of the reasons for removal currently shows:

- 24 (48%) returned for rod-end blister problem
- 14 (34%) returned for scheduled evaluation/test
- 9 (18%) returned for maintenance damage

Table 4 lists each of the recorded removals and the disposition associated with the removal.

Table 1. — Spoiler Service-Evaluation Program Graphite-Epoxy Spoilers only (As of April 30, 1977)

Spoiler serial number	Airline[a]	Hours at installation	Landings st installation	Current hours	Current landings	Net hours	Net landings
0001R	PI	5 681	3 056	13 119	14 123	7 438	11 067
0002	Test	—	—	—	—	—	—
0003	PSA	8 095	12 842	9 018	14 379	923	1 537
0003	VASP	9 018	14 379	15 997	22 045	6 979	7 666
0004	PSA	8 161	12 965	9 018	14 379	857	1 414
0004	VASP	9 018	14 379	15 9997	22 045	6 979	7 666
0005	PSA	8 095	12 842	9 018	14 379	923	1 537
0005	VASP	9 018	14 379	15 997	22 045	6 979	7 666
0006	PSA	8 161	12 965	9 018	14 379	857	1 414
0006	VASP	9 018	14 379	15 997	22 045	6 979	7 666
0007	NZ	10 861	15 053	18 723	25 567	7 862	10 514
0008	NZ	10 861	15 053	18 723	25 567	7 862	10 514
0009	NZ	10 861	15 053	16 147	22 112	5 286	7 059
0010	NZ	10 861	15 053	18 723	25 567	7 862	10 514
0011	LH	11 274	15 681	19 551	25 989	8 277	10 308
0012	LH	11 274	15 681	14 694	19 964	3 420	4 283
[b]0012	LH	15 148	20 528	15 793	21 324	645	796
[b]0012	LH	15 940	21 518	19 551	25 989	3 611	4 471
0013	LH	11 274	15 681	19 551	25 989	8 277	10 308
0014	LH	11 274	15 681	13 329	18 216	2 055	2 535
0015	PSA	8 651	13 711	9 399	14 936	748	1 225
0015	VASP	9 399	14 936	11 689	17 594	2 290	2 658
[b]0015	VASP	13 411	19 607	16 442	22 929	3 031	3 322
0016	PSA	8 651	13 711	9 399	14 036	748	1 225
0016	VASP	9 399	14 936	16 442	22 929	7 043	7 993
0017	PSA	8 651	13 711	9 399	14 936	748	1 225
0017	VASP	9 399	14 936	12 432	18 474	3 083	3 538
[b]0017	VASP	13 411	19 607	16 442	22 929	3 031	3 322
0018	PSA	8 651	13 711	9 399	14 936	748	1 225
0018	VASP	9 399	14 936	11 689	17 594	2 290	2 658
[b]0018	VASP	13 411	19 607	16 442	22 929	3 031	3 322
0019	LH	11 200	14 884	19 244	24 955	8 044	10 071
0020	LH	11 200	14 884	19 244	24 955	8 044	10 071
0021	LH	11 200	14 884	14 653	19 211	3 453	4 327
[b]0021	LH	15 425	20 178	19 244	24 955	3 819	4 777
0022	LH	11 200	14 884	19 244	24 955	8 044	10 071
0023	Aloha	9 207	24 932	16 148	43 851	6 941	18 919
0024	Aloha	9 207	24 932	10 974	29 694	1 767	4 762
[b]0024	Aloha	12 071	32 691	16 148	43 851	4 077	11 160
0025	Aloha	9 207	24 932	12 964	35 165	3 757	10 233
0026	Aloha	9 207	24 932	12 071	32 691	2 864	7 759
[b]0026	Aloha	8 287	14 823	10 395	20 494	2 108	5 671
0027	PI	12 329	20 204	20 275	32 262	7 946	12 058
0028	PI	13 747	22 449	16 387	26 396	2 640	3 947
[b]0028	PI	17 201	27 670	21 920	34 735	4 719	7 065
0029	PI	12 329	20 204	20 275	32 262	7 946	12 058

See footnotes at end of table.

Table 1. — Continued

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0030	PI	13 747	22 449	21 920	34 735	8 173	12 286
0031	PI	13 747	22 449	21 920	34 735	8 173	12 286
0032	PI	12 329	20 204	14 411	23 348	2 082	3 144
[b]0032	PI	15 259	24 624	20 275	32 262	5 016	7 638
0033	PI	13 747	22 449	21 920	34 735	8 173	12 286
0034R	PI	12 329	20 204	20 275	32 262	7 946	12 058
0035	PI	5 681	3 056	7 673	5 964	1 992	2 908
[b]0035	PI	8 542	7 300	13 119	4 123	4 577	6 823
0036	PI	5 681	3 056	7 663	5 945	1 982	2 889
[b]0036	PI	8 542	7 300	13 119	14 123	4 577	6 823
0037	PI	5 681	3 056	13 119	14 123	7 438	11 067
0038	Aloha	11 340	30 745	16 018	43 699	4 678	12 954
				Subtotal		261 788	386 759
0041	Test	—	—	—	—	—	—
0042	PSA	5 003	8 092	9 600	16 525	4 597	8 433
0042	FL	9 600	16 525	14 212	21 539	4 612	5 014
0043	PSA	4 993	8 068	9 600	16 525	4 607	8 457
0043	FL	9 600	16 525	14 212	21 539	4 612	5 014
0044	PSA	5 003	8 092	9 600	16 525	4 597	8 433
0044	FL	9 600	16 525	13 201	20 370	3 601	3 845
0045	PSA	4 993	9 068	6 896	11 280	1 902	3 212
0045	FL	10 064	16 998	14 212	21 539	4 148	4 541
0046	Aloha	6 447	9 087	12 143	24 173	5 696	15 086
0047	Aloha	6 447	9 087	10 256	19 089	3 809	10 002
[b]0047	FL	14 728	16 350	16 967	18 862	2 239	2 512
0048	Aloha	6 447	9 087	9 103	16 022	2 656	6 935
[b]0048	Aloha	8 287	14 823	11 005	22 141	2 718	7 318
0049	Aloha	6 447	9 087	12 050	23 911	5 603	14 824
0050	NZ	10 539	14 075	15 771	21 303	5 232	7 228
0051	NZ	10 539	14 075	18 412	24 825	7 873	10 750
0052	NZ	10 539	14 075	14 057	18 964	3 518	4 889
[b]0052	NZ	14 707	19 835	18 412	24 825	3 705	4 990
0053	NZ	10 539	14 075	13 138	17 747	2 599	2 672
0054	LH	11 152	15 328	17 899	23 824	6 747	8 946
0055	LH	11 152	15 328	19 341	25 544	8 189	10 216
0056	LH	11 152	15 328	19 341	25 544	8 189	10 216
0057	LH	11 152	15 328	15 633	20 997	4 481	5 669
0058	PSA	8 476	13 644	9 402	15 241	926	1 597
0058	VASP	9 402	15 241	16 222	22 794	6 820	7 553
0059	PSA	8 476	13 644	9 402	15 241	926	1 597
0059	VASP	9 402	15 241	10 900	17 164	1 498	1 923
0059	VASP	13 181	19 621	16 222	22 794	3 041	3 173
0060	PSA	8 476	13 644	9 402	15 241	926	1 597
0060	VASP	9 402	15 241	14 715	21 102	5 313	5 861

See footnotes at end of table.

Table 1. — Continued

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0061	PSA	8 476	13 644	9 402	15 241	926	1 597
0061	VASP	9 402	15 241	16 222	22 794	6 820	7 553
0062	LH	11 450	15 759	19 462	25 797	8 012	10 033
0063	LH	11 450	15 759	19 462	25 792	8 012	10 033
0064	LH	11 450	15 759	19 462	25 792	8 012	10 033
0065	LH	11 450	15 759	19 462	25 792	8 012	10 033
0066	NZ	10 787	14 648	14 184	19 120	3 397	4 472
[b]0066	NZ	14 602	19 678	18 574	25 213	3 972	5 535
0067	NZ	10 787	14 648	18 574	25 213	7 787	10 565
0068	NZ	10 787	14 648	18 574	25 213	7 787	10 565
0069	NZ	10 787	14 648	18 574	25 213	7 787	10 565
[b]0069	NZ	10 787	14 648	18 574	25 213	7 787	10 565
0070	PI	13 908	22 649	22 080	35 141	8 172	12 492
0071	PI	13 908	22 649	22 080	35 141	8 172	12 492
0072	PI	13 908	22 649	22 080	35 141	8 172	12 492
0073	PI	15 070	24 630	22 221	35 351	7 151	10 721
0074	PI	13 908	22 649	19 600	31 548	5 692	8 899
0074	FL	14 728	16 350	16 967	18 862	2 239	2 512
0075	PI	15 070	24 630	22 221	35 351	7 151	10 721
0076	PI	15 070	24 630	22 221	35 351	7 151	10 721
0077	PI	15 070	24 630	22 221	35 351	7 151	10 721
0078	Aloha	9 343	25 410	11 340	30 728	1 997	5 318
[b]0078	Aloha	9 103	16 022	12 143	24 173	3 040	8 151
				Subtotal		261 992	389 277
0081	Test	—	—	—	—	—	—
0082	LH	11 560	16 962	19 723	29 524	8 163	12 562
0083	LH	11 560	16 962	15 286	22 013	3 726	5 051
[b]0083	LH	16 901	26 080	19 723	29 524	2 822	3 444
0084	LH	11 560	16 962	15 286	22 013	3 726	5 051
[b]0084	LH	16 576	25 672	19 723	29 524	3 147	3 852
0085	LH	11 560	16 962	15 896	23 901	4 336	6 939
[b]0085	LH	16 901	26 080	19 723	29 524	2 822	3 444
0086	NZ	5 587	8 565	13 365	19 104	7 778	10 539
0087	NZ	5 587	8 565	9 516	13 797	3 929	5 232
[b]0087	NZ	10 647	15 393	13 365	19 104	2 718	3 711
0088	NZ	5 587	8 565	9 516	13 797	3 929	5 232
[b]0088	NZ	10 647	15 393	12 556	18 020	1 909	2 627
0089	NZ	5 587	8 565	7 272	10 794	1 685	2 229
[b]0089	NZ	8 771	12 820	12 556	18 020	3 785	5 200
0090	Aloha	5 623	7 992	6 788	10 937	1 165	2 945
[b]0090	Aloha	11 344	30 728	16 018	43 699	4 674	12 971
0091	Aloha	5 623	7 992	8 287	14 823	2 664	6 831
[b]0091	Aloha	12 964	35 165	16 148	43 851	3 184	8 686
0092	Aloha	5 623	7 992	11 005	22 141	5 382	14 149

See footnotes at end of table.

Table 1. — Concluded

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0093	PI	13 879	22 839	16 461	26 759	2 582	3 920
[b]0093	PI	17 333	28 122	21 797	34 851	4 464	6 729
0094	PI	13 879	22 839	16 461	26 759	2 582	3 920
[b]0094	PI	17 333	28 122	22 039	35 217	4 706	7 095
0095	PI	13 879	22 839	22 039	35 217	8 160	12 378
0096	PI	13 879	22 839	22 039	35 217	8 160	12 378
0097	—	—	—	—	—	—	—
0098	Aloha	9 244	25 150	16 018	43 699	6 774	18 549
0099	PI	10 290	15 517	18 724	28 324	8 434	12 807
0100	PI	12 641	20 584	20 652	32 721	8 011	12 137
0101	PI	10 290	15 517	18 724	28 324	8 434	12 807
0102	PI	10 290	15 517	18 724	28 324	8 434	12 807
0103	PI	12 641	20 584	20 652	32 721	8 011	12 137
0104	Aloha	9 244	25 150	11 340	30 745	2 096	5 595
0105	Aloha	9 244	25 150	9 343	25 410	99	260
[b]0105	Aloha	6 916	11 247	9 287	14 823	1 371	3 576
0106	Aloha	5 623	7 992	11 005	22 141	5 382	14 149
0107	Aloha	9 244	25 150	16 018	43 699	6 774	18 549
0108	PSA	8 621	13 711	9 568	15 160	947	1 449
0108	VASP	9 568	15 160	15 342	21 726	5 774	6 566
0109	PSA	8 621	13 711	9 568	15 160	947	1 449
0109	VASP	9 568	15 160	12 174	18 313	2 606	3 153
0110	PSA	8 261	13 711	9 568	15 160	947	1 449
0110	VASP	9 568	15 160	16 464	23 006	6 896	7 846
0111	PSA	8 621	13 711	9 568	15 160	947	1 449
0111	VASP	9 568	15 160	12 174	18 313	2 606	3 153
[b]0111	VASP	13 369	19 647	16 464	23 006	3 095	3 359
0112	LH	11 587	16 011	15 179	20 569	3 592	4 558
[b]0112	LH	16 309	21 974	19 433	25 846	3 124	3 872
0113	LH	11 587	16 011	19 433	25 846	7 846	9 835
0114	LH	11 587	16 011	14 601	19 849	3 014	3 838
[b]0114	LH	15 179	20 569	19 433	25 846	4 254	5 277
0115	LH	11 587	16 011	19 433	25 846	7 846	9 835
0116	PI	10 290	15 517	18 529	28 010	8 239	12 493
0117	PI	12 641	20 584	20 657	32 721	8 011	12 137
0118	PI	12 641	20 584	18 147	29 062	5 506	8 478
[b]0118	PI	19 709	31 351	20 652	32 721	943	1 370
				Subtotal		243 158	392 054
				Grand Total		766 938	1,168,090

[a] PI Piedmont Airlines
VASP Viacao Aerea Sao Paulo Airlines, Brazil
NZ New Zealand National Airways
LH Lufthansa German Airlines
FL Frontier Airlines

[b]Reinstallation

Table 2. — Flight spoiler service experience (Through April 30, 1977)

Airline	Number of aircraft in evaluation	Number of spoilers in evaluation	Total spoiler hours since installation	Total spoiler landings since installation
PSA	0	0	29 747	51 521
Aloha	4	16	91,276	245 352
New Zealand	4	16	108 262	146 602
Lufthansa	6	24	175 761	224 305
Piedmont	8	32	244 307	369 255
VASP	4	16	96 134	107 617
Frontier	2	6	21 451	23 438
Totals	28	110*	766 938	1 168 090

*Current total is 92 spoilers, with 18 spoilers either inactive or retired

Table 3. — Spoiler Service Evaluation Program (All-Composite, Polysulfone)

Spoiler serial number	Airline	Hours at installation	Landings at installation	Current hours*	Current landings*	Net hours	Net landings
0306	Aloha	13 572	36 811	14 843	40 236	1 271	3 425
0307	Aloha	10 256	19 089	11 165	21 498	909	7 409
0308	PI	19 600	31 548	20 540	32 962	940	1 414
0309	—	—	—	—	—	—	—
0310	NZ	16 313	22 047	17 071	23 044	758	997
0311	NZ	16 313	22 047	17 000	22 951	687	904
0312R	—	—	—	—	—	—	—
0313	LH	17 134	22 875	17 899	23 824	765	949
0314	LH	17 265	23 192	18 110	24 246	845	1 054
0315	PI	18 147	29 062	91 241	30 677	1 094	1 615
0316	FL	14 764	16 390	15 078	17 500	314	1 110
0317	FL	14 764	16 390	15 078	17 500	314	1 110
				Totals		7 897	14 987

*All 0300 series spoilers currently inactive

Table 4. — Flight Spoiler Removal Summary (As of April 30, 1977)*

Spoiler serial number	Airline	Date removed	Reason for removal	Action taken	Final disposition
0009	NZ	2-4-76	Spar corrosion	Analyze only	Await disp.
0012	Lufthansa	3-4-75	Upper skin blister	NDT & repair	Reinstalled
0014	Lufthansa	7-29-74	1-yr evaluation	NDT & repair	Static test
0015	VASP	5-13-75	Upper skin blister	NDT & repair	Reinstalled
0017	VASP	9-21-75	2-yr evaluation	NDT	Reinstalled
0018	VASP	5-13-75	Upper skin blister	NDT & repair	Reinstalled
0021	Lufthansa	3-29-75	Upper skin blister	NDT & repair	Reinstalled
0024	Aloha	7-11-74	Upper skin blister	NDT & repair	Reinstalled
0025	Aloha	8-18-75	2-yr evaluation	NDT	Static test
0026	Aloha	2-25-75	Upper skin blister	NDT & repair	Reinstalled
0026	Aloha	11-11-76	3-yr evaluation	NDT	Static test
0028	Piedmont	2-24-75	1-yr evaluation	NDT	Reinstalled
0032	Piedmont	1-28-75	Upper skin blister	NDT & repair	Reinstalled
0035	Piedmont	4-18-75	Upper skin blister	NDT & repair	Reinstalled
0036	Piedmont	4-16-75	Upper skin blister	NDT & repiar	Reinstalled
0045	PSA/Frontier	7-14-74	1-yr evaluation	NDT	Reinstalled
0047	Aloha	1-7-76	Replaced by Task II	NDT	Await reinst
0048	Aloha	2-25-75	Upper skin blister	NDT & repair	Reinstalled
0050	NZ	1-28-76	Spar corrosion	Analyze only	Scrapped
0052	NZ	2-27-75	Upper skin blister	NDT & repair	Reinstalled
0053	NZ	9-24-74	1-yr evaluation	NDT	Static test
0054	Lufthansa	11-11-76	3-yr evaluation	NDT	Static test
0057	Lufthansa	9-7-75	2-yr evaluation	NDT	Static test
0059	VASP	1-14-75	Upper skin blister	NDT & repair	Reinstalled
0060	VASP	9-2-76	3-yr evaluation	NDT	Reinstalled
0066	NZ	2-27-75	Upper skin blister	NDT & repair	Reinstalled
0074	Piedmont	4-27-76	2-yr evaluation	NDT	Reinstalled
0078	Aloha	10-24-74	Upper skin blister	NDT & repair	Reinstalled
0083	Lufthansa	5-17-75	Maintenance damage	NDT & repair	Reinstalled
0084	Lufthansa	5-17-75	Upper skin blister	NDT & repair	Reinstalled
0085	Lufthansa	9-4-75	2-yr evaluation	NDT	Reinstalled
0087	NZ	6-11-75	Upper skin blister	NDT & repair	Reinstalled
0088	NZ	6-11-75	Upper skin blister	NDT & repair	Reinstalled
0089	NZ	6-21-74	Maintenance damage	NDT & repair	Reinstalled
0090	Aloha	5-2-74	Upper skin blister	NDT & repair	Reinstalled
0091	Aloha	5-16-75	Upper skin blister	NDT & repair	Reinstalled
0093	Piedmont	4-1-75	Upper skin blister	NDT & repair	Reinstalled
0094	Piedmont	4-1-75	1-yr evaluation	NDT	Reinstalled
0104	Aloha	10-25-74	1-yr evaluation	NDT	Static test
0105	Aloha	10-17-73	Upper skin blister	NDT & repair	Reinstalled
0105	Aloha	5-16-75	2nd upper skin blister	NDT & repair	Scrapped
0109	VASP	7-29-75	2-yr evaluation	NDT	Static test
0111	VASP	7-29-75	Upper skin blister	NDT & repair	Reinstalled
0112	Lufthansa	6-20-75	Maintenance damage	NDT & repair	Reinstalled
0114	Lufthansa	3-9-75	Upper skin blister	NDT & repair	Reinstalled
0115	Lufthansa	11-9-76	3-yr evaluation	NDT	Reinstalled
0116	Piedmont	4-4-77	3-yr evaluation	NDT	Static test
0118	Piedmont	5-18-76	Replaced by Task II	NDT	Reinstalled

*Current unscheduled removals in Table 8

STATIC TEST RESULTS

During this reporting period, a total of six spoilers were removed from the flight service program for evaluation and test. Five of these spoilers were removed to satisfy the third-year removal requirement and one spoiler was removed to complete the two-year removal requirement. The sixth three-year spoiler is scheduled for removal in May 1977. All removed spoilers were reinspected using the NDI color C-scan and the results compared to the scan records made at the time of original fabrication. No detectable differences were noted in this comparison. The second-year spoiler was returned to the flight service program. Three of the third-year spoilers (S/N 0026, 0054, and 0116) were then selected to be destructively tested to measure residual static strength following the specified calendar period of exposure. Table 5 contains the data relative to the third-year removals. Table 6 is repeated from reference 2 to complete the two-year data.

Table 5. – Static Test Results (Third Year)

Spoiler serial number	Airline	NDI results	Failure load % DLL	Static test results		Time in service	Flight hours
				% change strength	% change stiffness		
0026(-1)	Aloha	Clear	230%	- 6%	- 4%	37 mos 4 days	4972
0027(-1)	PI	Removal in process	–	Not scheduled for test		–	–
0054(-2)	LH	Clear	218%	-25%	-13%	36 mos 0 day	6747
0060(-2)	VP	Clear	–	Not tested		36 mos 26 days	6239
0115(-3)	LH	Clear	–	Not tested		35 mos 26 days	6735
0116(-3)	PI	Clear	247%	+ 2%	0%	36 mos 14 days	8239

Table 6. – Static Test Results (Second Year)

Spoiler serial number	Airline	NDI results	Failure load % DLL	Static test results		Time in service	Flight hours
				% change strength	% change strength		
0017(-1)	VP	Clear	–	Not tested		25 mos 19 days	3780
0025(-1)	Aloha	Clear	260%	+ 6%	0%	24 mos 0 days	3757
0057(-2)	LH	Clear	257%	-11%	- 5%	24 mos 1 day	4481
0074(-2)	PI	Clear	–	Not tested		25 mos 23 days	5692
0085(-3)	LH	Clear	–	Not tested		23 mos 22 days	4336
0109(-3)	VP	Clear	237%	- 2%	-11%	22 mos 29 days	3553

A plot of the residual static strength data accumulated to date appears in figure 2, and is plotted as a function of time. This data not only continues to point out the scatter in the strength data being collected, but begins to show an identifiable trend relative to both the 250° F curing system and the 350° F curing systems. As shown in figure 2, both 350° F systems are maintaining a relative stability in residual strength as contrasted to the 250° F system.

To assist in better understanding the magnitude of data scatter, additional static tests have been performed on 15 spoiler panels (P/N 65-76327-2, T300/5209 material system). The purpose of this test series was to establish a range of variation of panel strengths resulting from variations in manufacturing quality. All 15 spoilers had zero sevice exposure and all 15 were fabricated in one production batch. All tests were conducted in the same test fixture and to the same test conditions. The test load is the single resultant load of the applied design airload pressure, with design limit load equal to 3 787 lbs. All test data is shown in table 7.

$$\text{Mean failure load (15 specimens)} = \frac{152\,405}{15} = 10\,160 \text{ lbs.}$$

$$\text{Mean failure load (15 specimens plus certification test)} = \frac{163\,349}{16} = 10\,209 \text{ lbs.}$$

$$\text{Strength ratio (max)} = \frac{10\,944}{10\,209} = 1.072$$

$$\text{Strength ratio (min)} = \frac{8\,709}{10\,209} = 0.853$$

The scatter band represented by these values is displayed graphically on figure 2. Consideration of this scatter contributes to the previous observation that the 350° F curing systems are maintaining relatively stable residual strength.

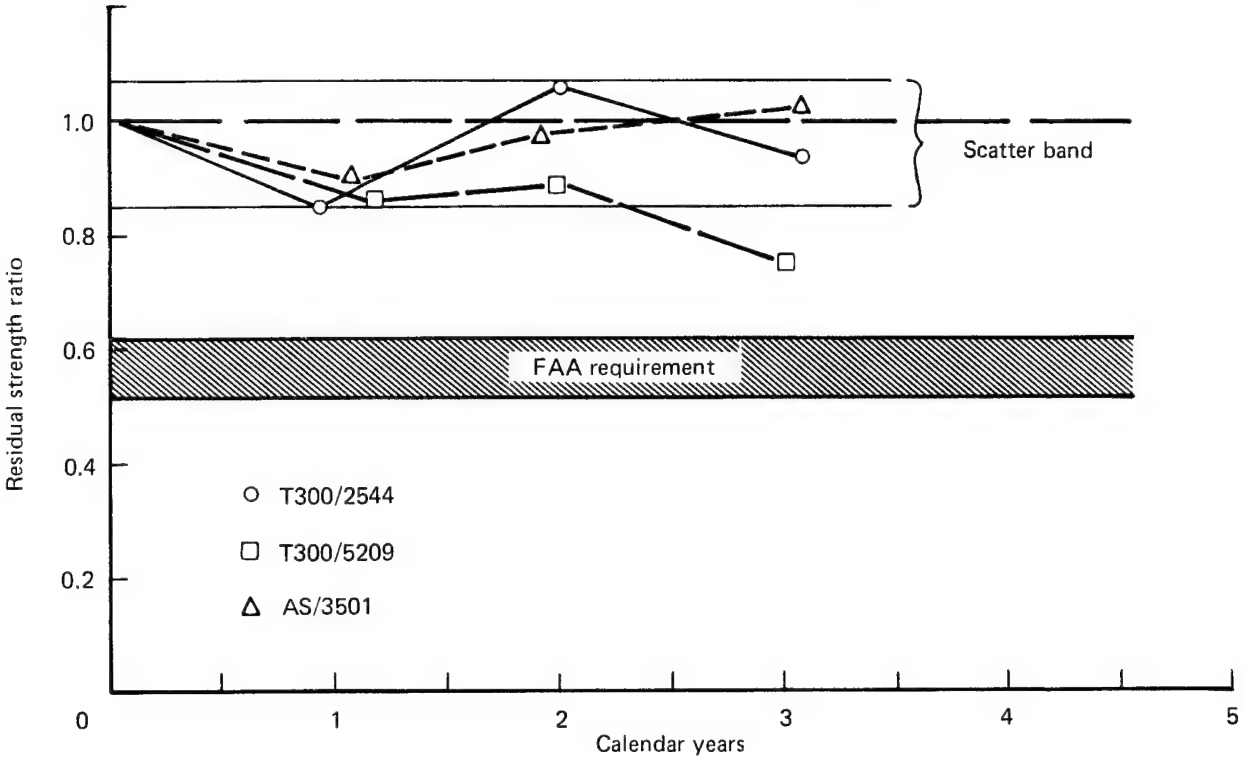

Figure 2. — Residual Strength After Exposure

Table 7. — Additional Zero-Time Spoiler Static Tests

Test number	Specimen serial number	Failure load, lb
1	219	9 946
2	222	9 543
3	211	10 421
4	216	10 848
5	225	10 736
6	220	8 709
7	204	10 153
8	203	10 296
9	208	10 404
10	210	10 304
11	224	10 400
12	214	10 813
13	213	10 408
14	201	10 549
15	217	8 875

CORROSION

The continuing concern for evidence of galvanic corrosion on the spoiler panels has indicated the desirability of differentiating between the areas of potential corrosion.

EXTERNAL

Twelve additional examples of corrosion of the -23 lower surface external doubler were reported from the annual spoiler examination activity. The corrosion on these doublers appears to be typical of incomplete surface protection rather than of electrochemical origin. None of these cases approached the severity of the example shown in reference 1, page 13. All twelve cases were refurbished by the operators and remained in service.

INTERNAL

Detection of internal corrosion on bonded assemblies has been exceptionally difficult, primarily due to lack of reliable nondestructive techniques. Principal reliance has been on visual observation of such phenomena as cracking or blistering.

No additional examples of exfoliation corrosion were reported from the completed fleet survey (ref. 2, p. 11). One additional case of exfoliation corrosion in the aluminum (7075-T6) spar element (fig. 3) was observed during the recent annual spoiler examination activity. This spoiler, S/N 0049 and operated by Aloha, was removed and returned to Boeing for examination. This spoiler has been committed to the repair cycle for refurbishment.

Figure 3. — Exfoliation Corrosion in Spar of S/N 0049

The examination technique for honeycomb core corrosion has been expanded to encompass all units that are tested in the static test laboratory. Each spoiler assembly is completely sectioned to enable visual observation of both bond lines in virtually all portions of the panel. Figure 4 shows a typical example of the degree of dissection achieved. A total of five static test spoilers (S/N 0057 and 0109 from the second year testing and S/N 0026, 0054, and 0116 from the third year testing) have been sectioned in this manner. Not only has there been a complete absence of corrosion in the honeycomb, but the physical appearance of both the honeycomb and the cured EA9628 adhesive compares favorably with newly manufactured assemblies.

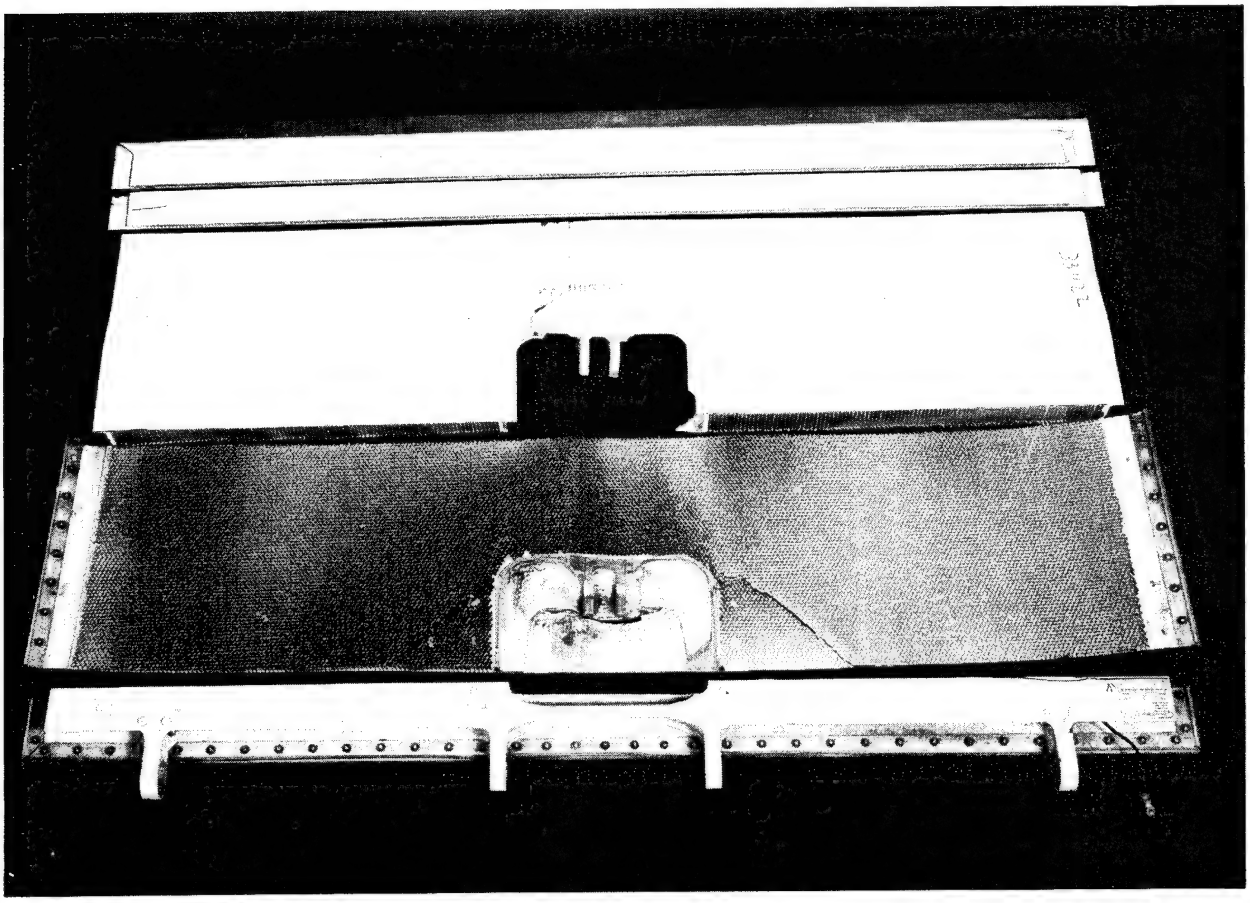

Figure 4. — Dissection of S/N 0054 for Corrosion Inspection

MOISTURE ABSORPTION

Initial efforts at moisture absorption measurement in this program involved gross spoiler panel weight measurements, from which differential weights were calculated. However, since the composite skins contribute approximately one-quarter of the entire panel weight, and the weight differences were necessarily quite small, the weight changes in these small quantities were virtually undetectable. In addition, changes in other quantities, such as paint erosion, dirt and grease accumulation, and fluid absorption in the seals contributed to erroneous conclusions in the weight calculations.

During the past year, a new and significantly more reliable system of moisture absorption measurement was devised. Since there exists within Boeing no suitable nondestructive technique for determining moisture content in laminates, the revised approach core-samples all spoiler panels scheduled for destructive testing. These samples are removed from environmentally exposed spoiler panels at locations near the trailing edge (see figure 5). This procedure maximizes the percentage of composite weight in the sample (approximately 65% composite by weight) while avoiding interference with the structural testing process and results.

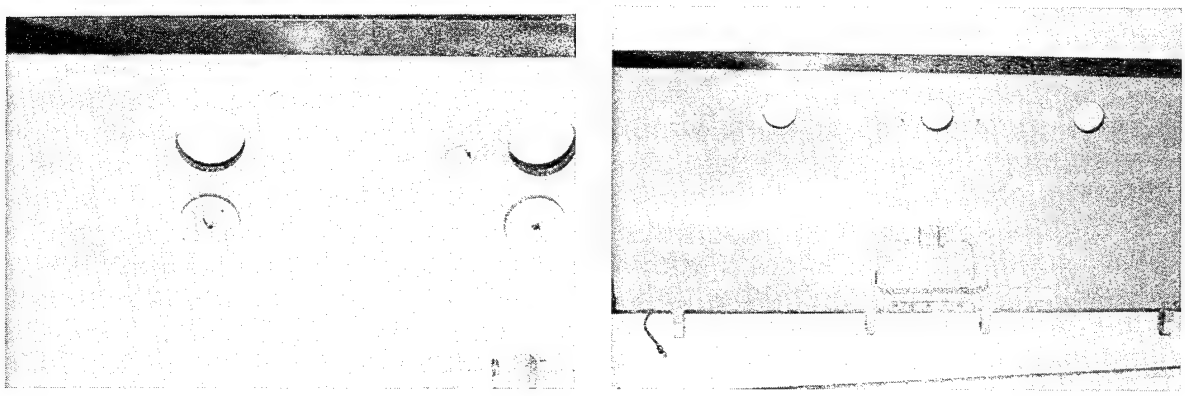

Figure 5. — Core Sampling of Environmentally Exposed Panels

The core samples (three per spoiler) are subjected to a 25-day drying environment at 160° F. The samples are weighed at discreet intervals in order to construct the weight-loss curve, an example of which is shown in figure 6. Actual weights of EA9628 adhesive and calculated weights of aluminum core are included in the final values. The final delta weights include moisture absorbed by the laminates and by the two layers of adhesive. Separation of the moisture content in each medium remains to be accomplished.

Two spoiler panels (S/N 0026 and S/N 0054) have been core-sampled prior to static test. The results of drying these samples are given in figure 6. Correlation of the effect of moisture absorption on the residual strength of the spoiler panels remains to be accomplished.

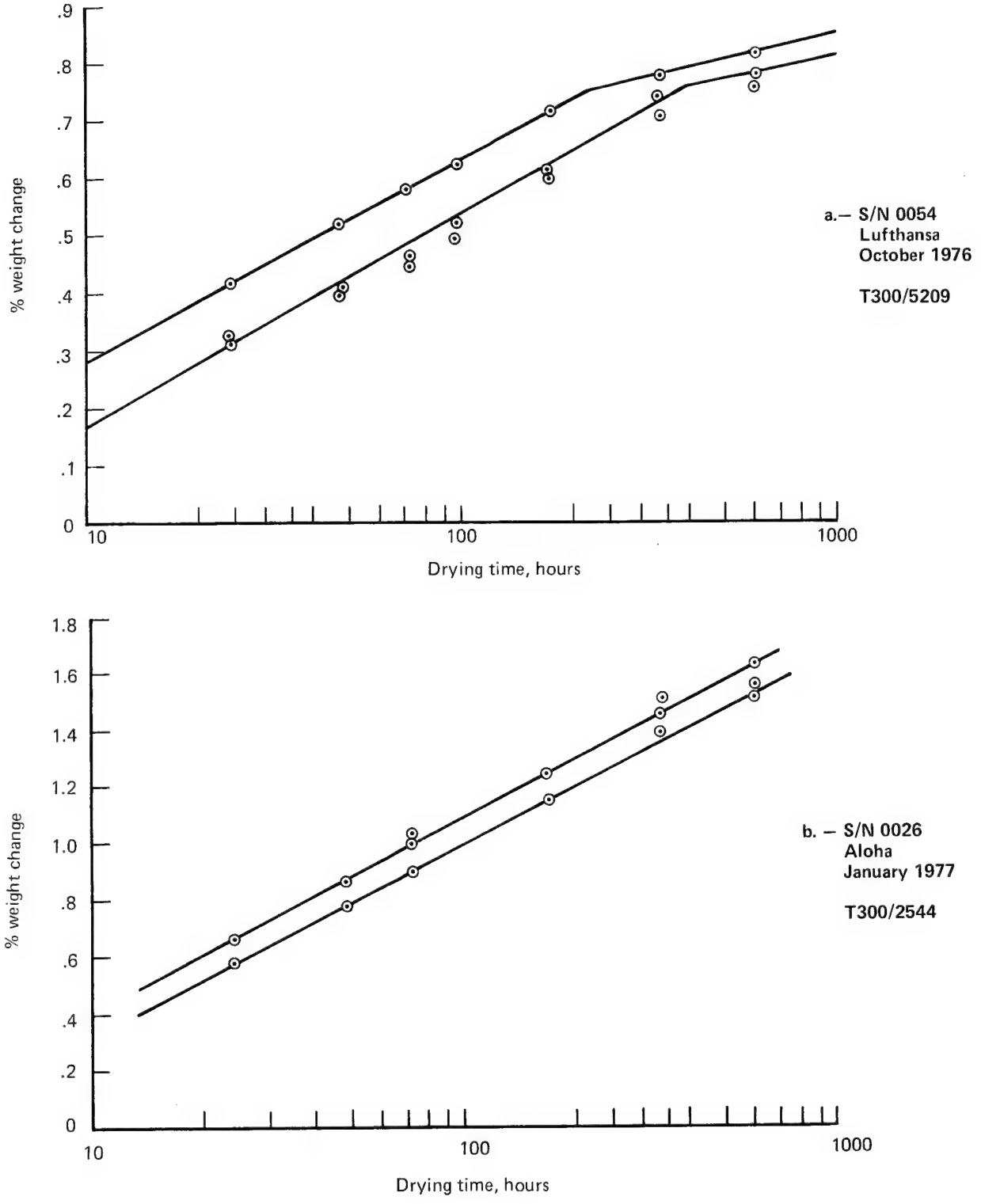

Figure 6. — Moisture Weight Change

SERVICE PROBLEMS/REPAIRS

The current reporting period has seen a significant reduction in service-related problems. As previously noted in the spoiler removal section, only six spoiler panels experienced unscheduled removals during this period. A summary of these removals is shown in table 8.

The one instance of the upper surface blister problem (S/N 0093) occurred as a result of inadvertent reinstallation of the larger actuator rod-end (ref. 1, p. 11) which was previously identified as the cause of this type of problem. Immediate corrective action was taken by the airline.

The additional instance of spar corrosion was a less severe example of the problem shown in figure 2 of reference 2. The spoiler panel is presently being repaired following examination and analysis of the problem.

The three cases of maintenance damage are illustrative of the ever-present risks associated with maintenance operations. Each instance of maintenance damage occurred inside the maintenance hanger area and was a result of activity involving aircraft components in the vicinity of the spoilers themselves. Two incidents resulted in damage to the trailing edge (figs. 7 and 8) and one panel received handling damage to the leading edge spar (fig. 9). The rate of maintenance damage approximates that of the previous year of operation.

Table 8. — Unscheduled Flight Spoiler Removals

Spoiler serial number	Airline	Date removed	Reason for removal	Action taken	Final disposition
0044	FL	12/29/76	External doubler delamination	NDT & repair	Reinstalled
0049	TS	4/13/77	Spar exfoliation corrosion	NDT	Repair in process
0088	NZ	11/22/76	Maintenance damage	NDT & repair	Reinstalled
0089	NZ	11/22/76	Maintenance damage	NDT & repair	Reinstalled
0093	PI	3/30/77	Upper skin blister	NDT	Repair in process
0108	VP	11/17/76	Maintenance damage	NDT & repair	Reinstalled

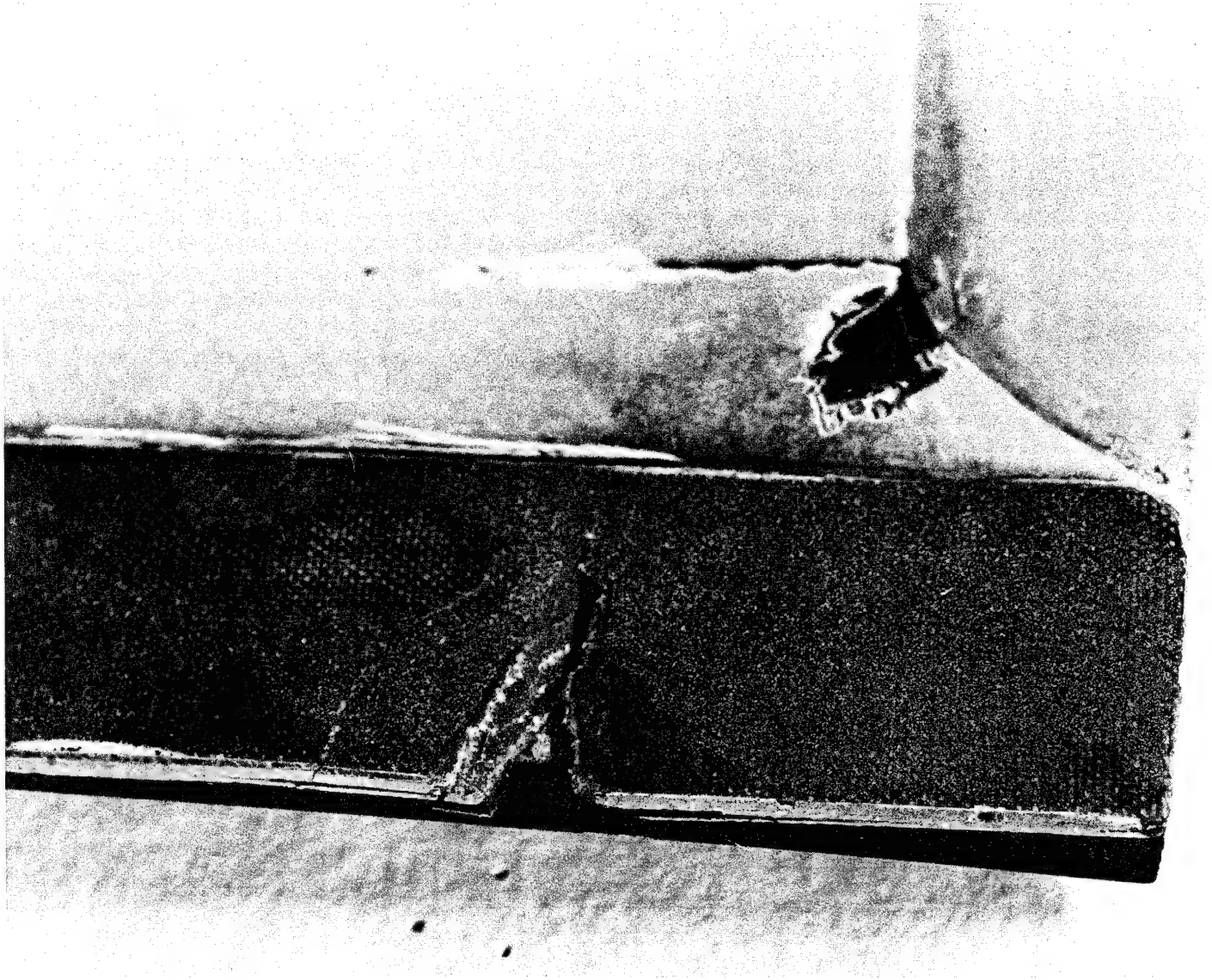

Figure 7. — Trailing Edge Damage — S/N 0089

Figure 8. — Trailing Edge Damage — S/N 0108

Figure 9. — Leading Edge Spar Damage — S/N 0088

TASK II - ALL COMPOSITE SPOILER

The initial introduction of the all-composite spoiler into flight service occurred on December 18, 1975, by Aloha Airlines. (ref. 1). Subsequent installations of two assemblies each were made by National Airways (NZ), Lufthansa, Piedmont, and Frontier Airlines. On August 6, 1976, Aloha Airlines reported a lower surface skin delamination on spoiler S/N 0306 (fig. 10) following a routine overnight inspection. No structural failure reports were filed prior to the routine inspection and subsequent removal from service. A similar examination of spoiler S/N 0307 showed similar, though less severe, evidence of delamination and strain. A precautionary examination by the remaining operators was conducted, and all remaining spoilers were removed from service to preclude any potential risks for the operators. All units have been returned to Boeing pending a decision on disposition.

Chemical analysis of skin samples removed from spoiler S/N 0306 have confirmed that the principal contaminants were phosphate esters which are principal ingredients in Skydrol 500. Additional evaluation steps are being investigated.

The service history of those all-composite spoilers deployed on revenue aircraft is documented in the "Flight Experience" section.

GROUND-BASED ENVIRONMENTAL SERVICE

Material property specimens were removed from the ground-based environmental exposure program following the third year of exposure. The specimens were returned from the various sites to NASA-Langley for laboratory evaluation. The reduced moisture absorption data has been plotted in figure 11, which also contains the first year data and the "NASA-only" second year moisture data. Current program plans call for a retrieval schedule at the completion of 1, 3, 5, 7 and 10 years of exposure.

The plotted data continued to exhibit a stabilizing trend, with an increasing scatter within the averages. The tabulated moisture data is presented in tables 9, 10, and 11. Plots of strength retention similar to those that appeared in references (1) and (2) are shown in figures 12, 13, and 14. The data for the strength retention plots is also included in tables 9, 10, and 11.

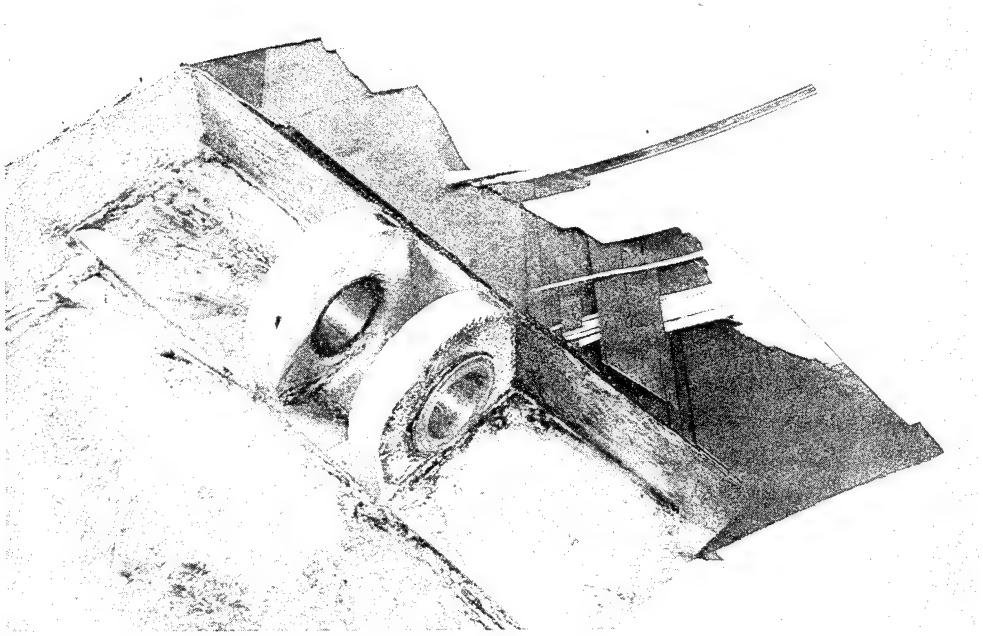

Figure 10. — Lower Surface Delamination—Aloha Spoiler S/N 0306

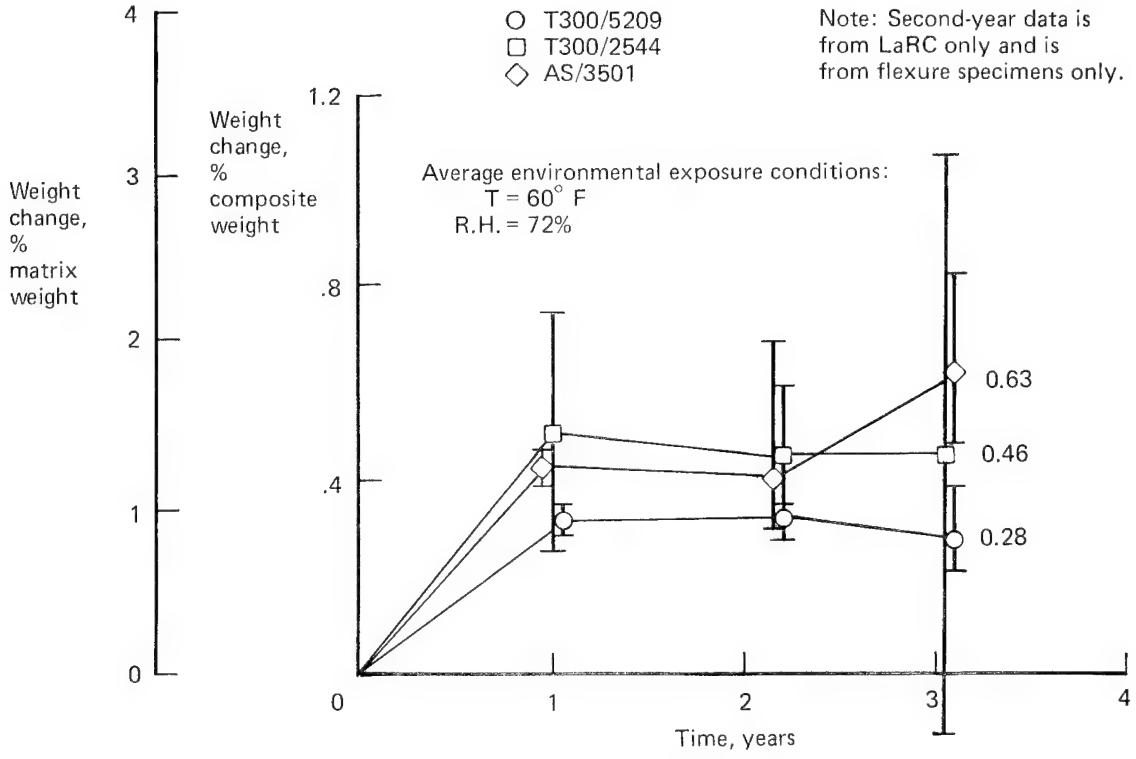

Figure 11. — Moisture Pickup in Exposed Epoxy-Matrix Laminates

Table 9. — Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens — Short-Beam Interlaminar Shear Tests

Exposure time, yr	Exposure location	Graphite material system	Number of specimens	Average failure stress		Average weight change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	5	77	11.2	—	—
3	LaRC	T300/5209	3	78	11.3	+0.0039	+0.51
3	Hawaii	T300/5209	3	81	11.8	+0.0045	+0.60
3	New Zealand	T300/5209	3	77	11.2	+0.0046	+0.61
3	Germany	T300/5209	3	82	11.9	+0.0039	+0.53
3	California	T300/5209	2	79	11.5	+0.0040	+0.54
3	LaRC* (painted specimens)	T300/5209	3	77	11.1	+0.0034	+0.41
3	Brazil	T300/5209	(unavail)	—	—	—	—
0 (baseline)	LaRC	T300/2544	4	81	11.7	—	—
3	LaRC	T300/2544	3	67	9.7	+0.0081	+1.34
3	Hawaii	T300/2544	3	77	11.1	-0.0183	-2.62
3	New Zealand	T300/2544	3	64	9.3	+0.0117	+1.86
3	Germany	T300/2544	3	59	8.6	+0.0078	+1.38
3	California	T300/2544	3	66	9.6	+0.0069	+1.23
3	LaRC* (painted specimens)	T300/2544	3	68	9.9	+0.0090	+1.35
3	Brazil	T300/2544	(unavail)	—	—	—	—
0 (baseline)	LaRC	AS/3501	5	87	12.6	—	—
3	LaRC	AS/3501	3	91	13.2	+0.0045	+0.78
3	Hawaii	AS/3501	3	81	11.8	+0.0298	+5.08
3	New Zealand	AS/3501	3	76	11.0	+0.0084	+1.43
3	Germany	AS/3501	3	89	12.9	+0.0048	+0.86
3	California	AS/3501	3	85	12.4	+0.0050	+0.91
3	LaRC* (painted specimens)	AS/3501	3	85	12.3	+0.0037	+0.60
3	Brazil	AS/3501	(unavail)	—	—	—	—

*Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 10. — Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens — Flexure[a] Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Number of specimens	Average failure stress		Average flexure modulus		Average weight change	
				MPa	ksi	GPa	psi (x 10^6)	grams	%[b]
0(baseline)	LaRC	T300/5209	5	1529	221.8	103.8	15.05	—	—
3	LaRC	T300/5209	3	1638	137.5	104.5	15.15	+0.0052	+0.24
3	Hawaii	T300/5209	3	1387	201.1	103.5	15.01	+0.0049	+0.23
3	New Zealand	T300/5209	3	1349	195.6	108.9	15.80	+0.0080	+0.38
3	Germany	T300/5209	3	1592	230.9	103.8	15.05	+0.0056	+0.26
3	California	T300/5209	3	1644	238.4	104.7	15.19	+0.0045	+0.22
3	LaRC[c] (painted specimens)	T300/5209	3	1519	220.3	105.2	15.26	+0.0087	+0.34
3	Brazil	T300/5209	(unavail)	—	—	—	—	—	—
0(baseline)	LaRC	T300/2544	5	1462	212.0	106.2	15.41	—	—
3	LaRC	T300/2544	3	1581	229.3	103.8	15.05	-0.0017	+0.26
3	Hawaii	T300/2544	3	1584	229.7	102.3	14.84	-0.0114	-0.26
3	New Zealand	T300/2544	3	1435	208.2	101.1	14.67	+0.0053	+0.63
3	Germany	T300/2544	3	1638	237.6	104.8	15.20	+0.0088	+0.81
3	California	T300/2544	3	1691	245.2	107.4	15.58	-0.0019	+0.25
3	LaRC[c] (painted specimens)	T300/2544	3	1633	236.9	105.1	15.25	+0.0153	+1.08
3	Brazil	T300/2544	(unavail)	—	—	—	—	—	—
0(baseline)	LaRC	AS/3501	5	1449	210.1	94.7	13.73	—	—
3	LaRC	AS/3501	3	1757	254.8	98.9	14.35	+0.0036	+0.53
3	Hawaii	AS/3501	3	1635	237.1	95.1	13.79	+0.0025	+0.47
3	New Zealand	AS/3501	3	1465	212.5	98.3	14.25	+0.0093	+0.83
3	Germany	AS/3501	3	1715	248.8	95.3	13.82	+0.0056	+0.63
3	California	AS/3501	3	1696	246.0	97.3	14.11	+0.0057	+0.64
3	LaRC[c] (painted specimens)	AS/3501	3	1770	256.7	101.8	14.77	+0.0077	+0.66
3	Brazil	AS/3501	(unavail)	—	—	—	—	—	—

[a]Flexure specimens were fabricated from laminates with ply orientations identical to spoiler skin orientation. Specimen length is oriented in the 90° direction of the laminate.

[b]Corrected to initial fully dry weight.

[c]Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 11. – Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens – Compression[a] Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Number of specimens	Average failure stress		Average weight change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	3	712	103.2	–	–
3	LaRC	T300/5209	3	698	101.2	+0.0640	+0.80
3	Hawaii	T300/5209	3	560	81.2	+0.0735	+0.93
3	New Zealand	T300/5209	3	674	97.8	+0.0945	+1.18
3	Germany	T300/5209	3	688	99.8	+0.0498	+0.62
3	California	T300/5209	3	654	94.9	+0.0846	+1.04
3	LaRC[b] (painted specimens)	T300/5209	3	662	96.0	+0.0531	+0.65
3	Brazil	T300/5209	(unavail)	–	–	–	–
0 (baseline)	LaRC	T300/2544	4	1029	149.2	–	–
3	LaRC	T300/2544	3	955	138.5	+0.0985	+1.39
3	Hawaii	T300/2544	3	812	117.7	+0.0964	+1.38
3	New Zealand	T300/2544	3	860	124.8	+0.1139	+1.63
3	Germany	T300/2544	3	985	142.8	+0.0639	+0.91
3	California	T300/2544	2	1046	151.7	+0.1014	+1.50
3	LaRC[b] (painted specimens)	T300/2544	3	926	134.3	+0.0865	+1.20
3	Brazil	T300/2544	(unavail)	–	–	–	–
0 (baseline)	LaRC	AS/3501	5	1107	160.5	–	–
3	LaRC	AS/3501	3	1003	145.5	+0.0583	+0.89
3	Hawaii	AS/3501	3	998	144.8	+0.0607	+0.94
3	New Zealand	AS/3501	3	953	138.2	+0.0741	+1.10
3	Germany	AS/3501	3	1080	156.6	+0.0464	+0.70
3	California	AS/3501	3	1045	151.5	+0.0779	+1.19
3	LaRC[b] (painted specimens)	AS/3501	3	1068	154.9	+0.0570	+0.87
3	Brazil	AS/3501	(unavail)	–	–	–	–

[a]Compression specimens were fabricated from laminates with ply orientations identical to spoiler skin ply orientation. Specimen length is oriented in the 90° direction of the skin laminate.

[b]Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

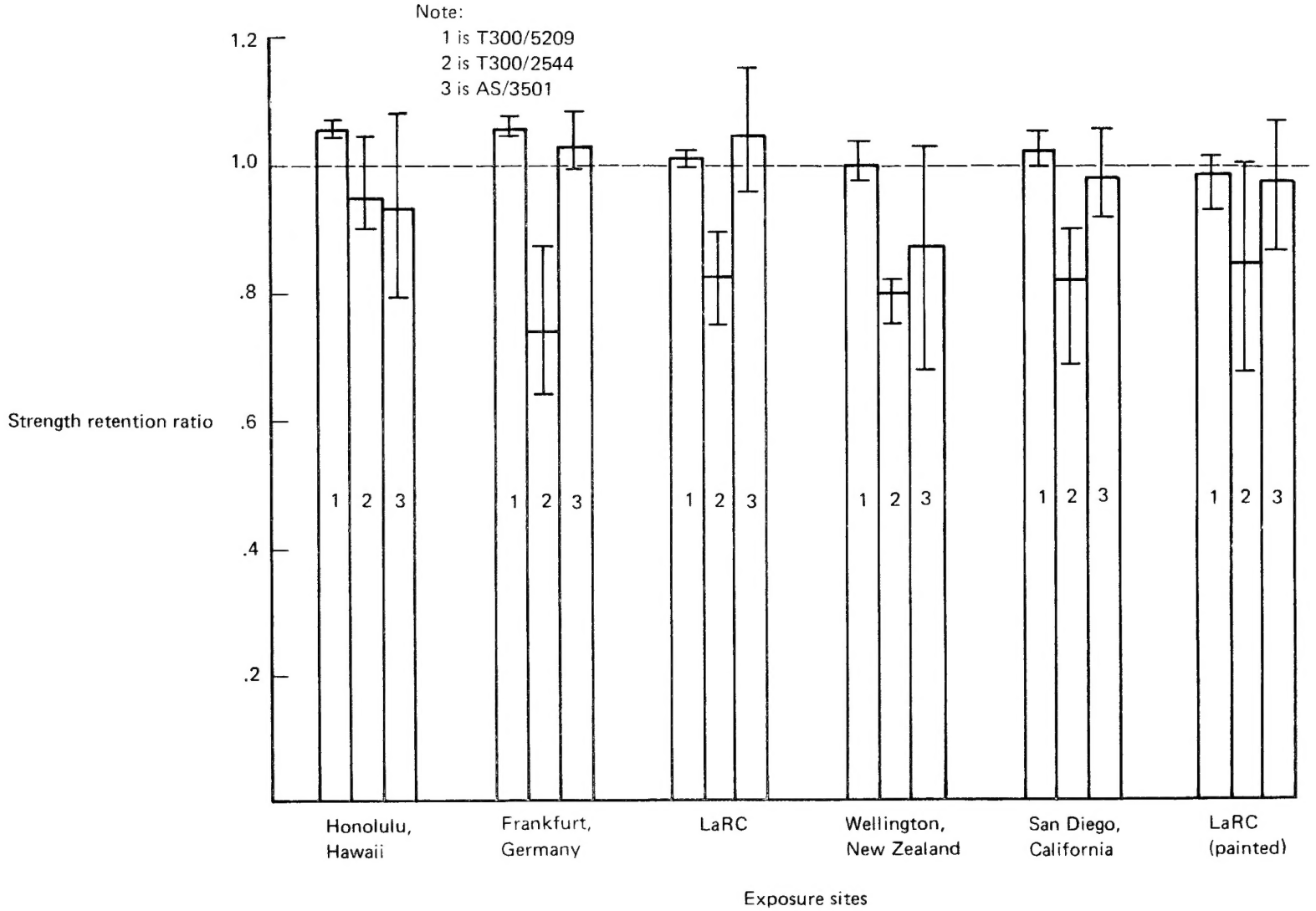

Figure 12. — Interlaminar Shear Strengths of Graphite-Epoxy Composites After 3 Years Outdoor Ground Exposure

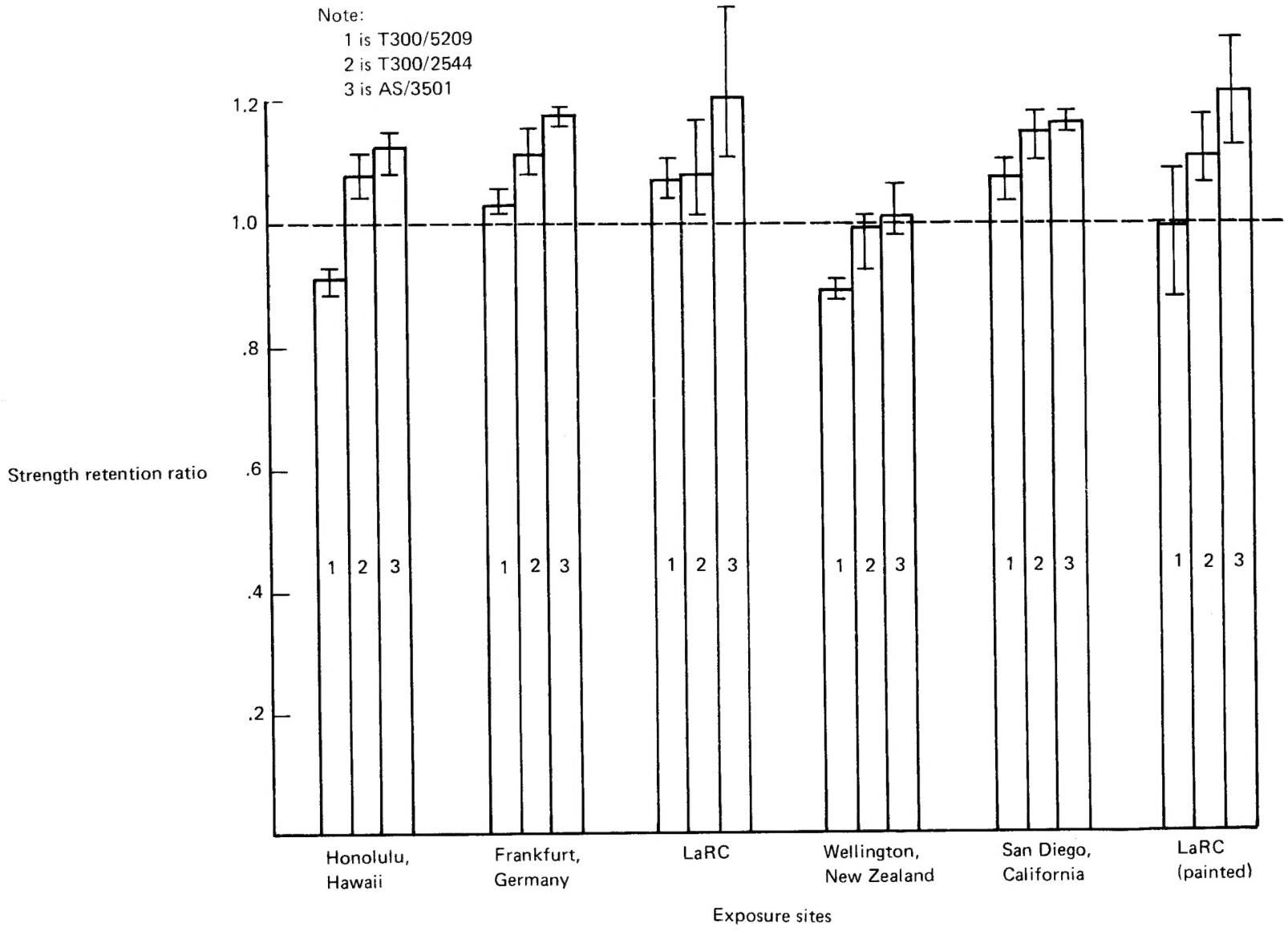

Figure 13. — Flexure Strengths of Graphite-Epoxy Composites After 3 Years Outdoor Ground Exposure

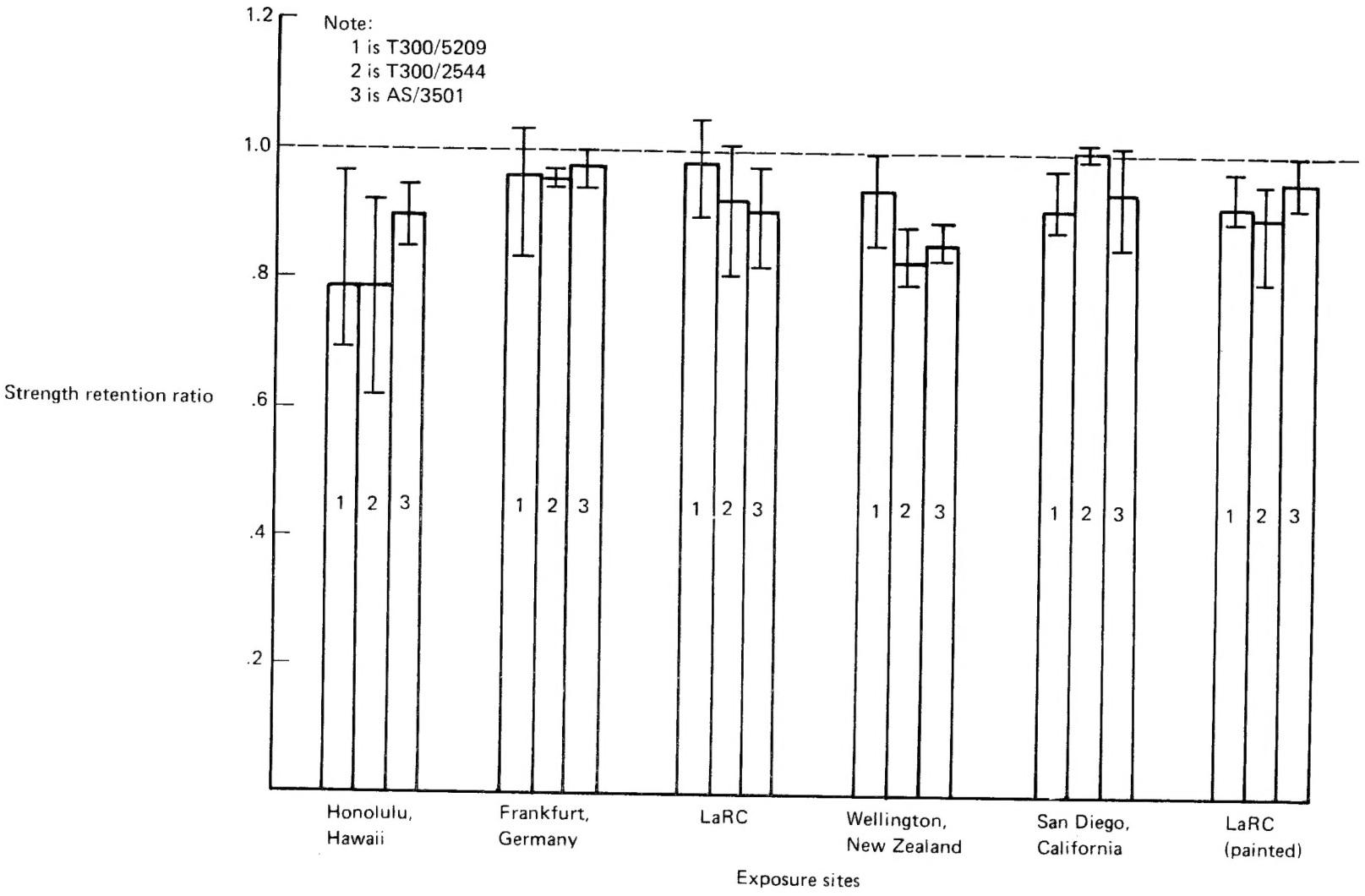

Figure 14. — Compression Strengths of Graphite-Epoxy Composites After 3 Years Outdoor Ground Exposure

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